The Environmental Kuznets Curve Case for the USA and the BRIC Countries

A Thesis

Presented to

The Academic Faculty

By

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In Partial Fulfillment

Of the Requirements for the Degree

Masters of Science in the

School of Economics

Georgia Institute of Technology

December 2009

The Environmental Kuznets Curve Case for the USA and the BRIC Countries

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Date Approved: November 19, 2009

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Summary

Previous literature on the Environmental Kuznets Curve has focused extensively on why or why not such a relationship is observed given specific scenarios. More recent literature has shifted attention towards factors that may explain differences in the distribution or threshold of the curve. The purpose of this paper is to determine why we witness different cutoff points for environmental improvement given the same dependent variable. For this analysis, the relationship between CO2 emissions and GDP growth is observed in the United States and the BRIC countries (Brazil, Russia, India and China) from 1981-2006. The results suggest that the standard for environmental improvement is lower for the BRIC countries compared with the United States. This means that the United States is more willing to accept pollution as a way of increasing income. However the income effect for environmental improvement occurs at an earlier stage for the BRIC countries. This has important implications for the pollution haven hypothesis and explaining the tradeoff between economic growth and pollution in developed and developing nations. Factors that explain this are FDI inflow, share of production from different industries, share of energy from different sources, and overall incentives.

Chapter 1

Introduction

Simon Kuznets was an American economist most famously known for winning the Nobel prize in economics in 1971. He is credited with discovering a relationship between income inequality and per capita income. If one were to look at a graph comparing this relationship you would find an inverted u-shape. Meaning there are low levels of income inequality when per capita income is low or high, however income inequality is high when per capita income is in the mid-range. This reverse u-shaped curve is now known as the Kuznets Curve.

Two decades later, G.M Grossman and A.B. Krueger conducted a separate study in which they found a similar relationship between environmental quality and per capita income. They discovered that at the lowest levels of per capita income, countries didn't have the capability to acquire more resources or increase production in order to harm the environment. However once per capita income started to increase, productivity grew leading to higher concentrations of sulfur dioxide and total suspended particulate matter. Eventually at a certain point of per capita income, environmental decline will start to decrease as concentrations of pollution will diminish. Since this relationship follows the same pattern as a Kuznets Curve, the authors decided to name this relationship the Environmental Kuznets Curve.

The discovery of such a relationship provides some important insights into the issue of environmental decline. Previously and even today there are assumed notions that economic growth will inevitably cause harm to the environment. Lawmakers are

constantly stressing the issue of the importance of protecting the environment. Some politicians are arguing in favor of green marketing as part of campaigns, while others such as Al Gore are lobbying in front of Congress and winning Oscars for movies depicting the severity of the situation. Indeed President Bush has come in for heavy criticism for not agreeing to sign the Kyoto Protocol for fear of hurting US industries. Yet all these arguments are biased in the sense that they are purely from an environmentalist's perspective or have alternative motives of candidates looking to gain votes.

Since this original paper was published in 1991, a wide variety of research has been conducted to confirm the existence of the Environmental Kuznets Curve. Previous literature has provided mixed results on the validity of such a relationship, with some studies corroborating with Grossman and Krueger's findings while others have not. In general the EKC has been found to apply to only certain types of pollutants and under certain circumstances. Several suggestions have been made to explain this inconsistency such as flawed methodology involving omitted variables, data collection problems, and individual country characteristics. However the majority of this literature has focused on identifying why or why not an EKC may exist given a specific circumstance. More recent literature has chosen to focus on why one witnesses differences in the distribution of the curve given different scenarios. For example when considering the same independent variable (type of pollutant) why would you see different cut off points when comparing different countries? Or given the situation where the cutoff point is not statistically different, why is pollution per capita still higher for some countries compared with others? Therefore the purpose of this paper will be to determine the factors which explain differences in the cutoff and threshold points of the Environmental Kuznets Curve?

The two curves being considered are for carbon dioxide emissions in the United States in one set and Brazil, Russian, India, and China in the other set. The rest of the paper is organized as follows: Chapter 2 gives a literature review on the subject and explains the choice of using these countries, Chapter 3 introduces the data and model being used, Chapter 4 reports all estimation results of the model, Chapter 5 is devoted to explaining differences between both estimation results, and Chapter 6 concludes.

Chapter 2

Literature Review

Historically speaking, the success of the human species is measured by an improvement in the standard of living. Yet the process of production involves inputs that hurt the environment (ex. cars, factories). Nevertheless, Grossman and Krueger would argue that eventually environment degradation will decrease, suggesting growth helps the environment. Indeed Grossman and Krueger used their findings to argue in favor of an expansion of the NAFTA based trade agreement that would safeguard the environment.[1] Conversely, the Environmental Kuznets Curve has been criticized for not applying to all pollutants and economic indicators. For example, the curve accurately describes the relationship for sulfur dioxide but not for certain ecosystems and soil fertility status. Grossman and Krueger published a few other papers after their initial one in order to study other possible environmental indicators, however they acknowledge the lack of comparable data.[2]

In 1995, Grossman and Kruger published another paper in an attempt to validate the existence of the Environmental Kuznets Curve. On this occasion they focused on different environmental factors which were urban air pollution, state of oxygen regime in river basins, fecal contamination of river basins, and contamination of river basins by heavy metals. Once again they found a relationship consistent with a Kuznets Curve with a turnoff point of nearly $8,000 (1985 dollars). However they found no evidence of a correlation for municipal waste in per capita criteria. Grossman and Krueger also point

[1] Grossman, Krueger 1991
[2] Grossman, Krueger 1995 pg. 372

out that the process of environmental improvement is not automatic. Even in the most affluent of nations, there has to be a persistent effort on behalf of citizens to attack environmental standards, and follow more environmentally protective production processes.[3]

Still others suggest that environmental improvement may not be as a result of the income effect. Chung-Chiang and Yi-Tui concluded while studying waste collection in Taipei, that a policy change based on a plastic bag fee caused an increase in marginal recycling. They used this to argue in favor of future waste management system which would allow for the conservation of natural resources.[4]

The issue of lobbying for environmental protection over economic growth gains significance when one considers recent efforts by many countries who are arguing in favor of regulating emissions levels. Specifically the Kyoto Protocol was anticipated to be a breakthrough agreement which called for a reduction of greenhouse gas emissions. Yet it's credibility was undermined when the United States did not agree to sign on. Huang, Lee and Wu published their findings on countries ability to meet reduction standards. They concluded that as many as 38 industrialized countries failed to meet their targets set by the Protocol and concerted efforts on behalf of the global community may not be able to achieve a reduction, even if there is an international body responsible for emissions reduction. The authors were not able to validate their assumption that greenhouse gas emissions would follow a relationship consistent with EKC.[5] What is

[3] Grossman, Krueger 1995 pg. 373-374
[4] Chung-Chiang, Yi-Tui 1007 pg. 64
[5] Huang, Lee and Wu 2007 pg. 244-246

noteworthy here is that they fail to account for the proportion of countries that are failing to meet standards (38 out of how many). Even though these countries are described as developed, an accurate representation of the model can not be achieved without considering all possible information.

Khanna and Plassman go a step further in authenticating the existence of an Environmental Kuznets Curve by performing an updated analysis on the relationship between total factor productivity and environmental decay. Previously it was assumed that differences in total factor productivity across countries would yield different scenarios for pollution which would allow for the existence of the EKC. While performing an econometric analysis on a model for the marginal rate of substitution between consumption and pollution, the authors concluded that differences in income and resource endowment is what allowed for the curve rather than differences in factor productivity. This finding is significant as it proves the hypothesis that economic growth alone does not account for reduction in pollution, rather it has to be coupled with additional income would allow for improvement in environmental quality.[6]

A few papers have suggested closely related reasons for the existence of a Kuznets curve when studying how economic growth affects the environment. For example Munasinghe suggests at the lowest levels of per capita income, economies are most probably agriculture based. Pollution within agrarian based economies is different and at lower levels compared with an industry based economy. Over time with economic growth per capita income would increase. This would allow people to move out of

[6] Khanna and Plassman 2007 pg. 56-58

subsistence level living and provide the ability to attain further amounts of resources. This process would coincide with an increase in emission rates of pollution associated with an industry based economy. However, once per capita income increases to a level above that which is necessary in order to purchase what you need, people will have the luxury to be able to make decision on what to do with their extra income. Invariably people will choose better health, which involves clean water, and less air pollution. If the economy grows even further into a service based economy there will be options of including specific policies on environmental protection/ regulation.[7] In this situation, the environment acts as a luxury good, which one can essentially purchase or improve with additional income.

Millimet et al, explore the modeling techniques used in estimating an Environmental Kuznets Curve. By using US state level data on nitrogen oxide and sulfur dioxide, they are able to estimate an Environmental Kuznets Curve by using a standard parametric and a semi parametric framework. Their conclusions state that modeling techniques were not significant in finding a relationship, however they argued in favor of a semi parametric framework as finding the tip of the curve is sensitive to such information.[8]

Gergel et al, shed some light on the issue of why the relationship between certain types of pollutants and economic growth follow the Environmental Kuznets Curve, while other don't. The authors argue that reducing pollution is strictly on an incentive basis. In their analysis, the authors are able to determine that the levels of pollutants that more

[7] Munasinghe 1999 pg. 90-104
[8] Millimet, List, and Stengos pg. 1047

directly affect human health are more likely to be reduced over time. By reviewing issues such as lake sediments, water clarity and real wealth per capita, they were able to find a relationship between wealth with certain types of pollutants and not with others.[9]

These papers basically present the main theories for the existence of an Environmental Kuznets Curve. However as mentioned earlier, the purpose of this paper is to determine factors which explain differences in the makeup of the curve. The choice of choosing Brazil, Russia, India, and China as one set is largely due to significant characteristics they share with one another. These four were jointly named the BRIC countries by Goldman Sachs due to the fact that they are among the fastest growing developing economies. When combined, they consist of 25% of the world's land and 40% of its population. Goldman Sachs predicts that by 2050 the BRIC countries will outperform the combined current richest countries in the world. It is a trend which gives these countries substantial influence in terms of political and economic cooperation, and the fact that they are still considered developing makes them an ideal candidate when considering the process countries go through from the beginning to the end of the EKC.

Each country is rich in terms of manufactured goods, services, and raw materials and readily available data make them an appropriate representative for developing economies. On the other hand, the United States was chosen as a representative for developed nations due to the fact that it has large trade links with each country. Therefore it would be interesting to see how interaction with a developed country such as the United States, affects a developing countries decision to start decreasing pollution as part

[9] Gergel, Bennett, Greenfield, King, Overdevest, and Stumborg pg. 557

of the production process. Existing theory points at the pollution haven hypothesis which states that companies will move production towards developing countries due to less strict environmental regulation. Additionally these developing countries will look to decrease regulation as a way of attracting investment.

Tamazian et al. do an analysis of the EKC in the BRIC countries, but focus additionally on financial development in the area. Their research finds that economic development and environmental degradation is consistent with the curve, however financial development is associated with the decline in CO2 emissions per capita. Hence their policy implication is that financial liberalization can lead to investment and R&D which will lead to environmental improvement. The idea here is to create incentives which will allow firms to produce long term technologies which reduce emissions standards. [10]

[10] Tamazian, Chousa, and Vadlamannati 2009 pg. 251-52

Chapter 3

Model

In the first set, time series data on CO2 emissions is used from the United States from 1981-2006. In the second set, panel data is used on CO2 emissions from the BRIC countries for the same years. All data is obtained from the World Bank's World Development Indicators database of 2008. The model being used is a parametric model which is standard in previous literature and will be of the form:

$$E_t = \alpha_0 + \alpha_1 t + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 Y_t^3 + \gamma Z_t + u_t$$

Where E is CO2 emissions per capita, Y is GDP per capita and Z is a vector of explanatory variables which explains variations in CO2 emissions. T is time and is meant to account for variations in technology over the years. Random effects specification is used for the BRIC panel in order to control for country specific unobserved heterogeneity. The following tables provide descriptive statistics on each of the variables. All monetary variables are converted into constant 2000 US dollars.

Table 1: For the USA

Variable:	Obs	Mean	Std. Dev	Min	Max
CO2 emission per capita (metric tons)	24	19.6375	0.8982169	18.2	21.1
GPD per capita	26	29903.85	4603.345	22200	37800
GDP per capita squared	26	9.15E+08	2.77E+08	4.95E+08	1.43E+09
Industry value added (% of GDP)	25	26.92	3.52432	22	34.1

Services value added (% of GDP)	25	71.24	4.059865	62.8	76.8
Energy Consumption (kg of oil equivalent)	25	2.03E+12	2.16E+11	1.69E+12	2.34E+12
Fossil fuel energy consumption	25	1.77E+12	1.68E+11	1.51E+12	2.02E+12
FDI inflow	26	8.82E+10	8.15E+10	1.05E+10	3.21E+11
Renewable usage (% of total energy usage)	25	3.3528	0.2819208	2.84	3.94

Table 2: For the BRIC countries:

Variable:	Obs	Mean	Std. Dev	Min	Max
CO2 emission per capita (metric tons)	85	2.972671	3.325582	0.531	13.3
GPD per capita	96	1625.771	1345.919	194	4040
GDP per capita squared	96	4436587	5378412	37496.45	1.64E+07
Industry value added (% of GDP)	96	36.60938	8.605128	25.3	50.2
Services value added (% of GDP)	96	46.61354	11.61459	21.7	68.8
Energy Consumption (kg of oil equivalent)	91	5.26E+11	3.62E+11	1.07E+11	1.72E+12
Fossil fuel energy consumption	91	3.98E+11	3.18E+11	5.69E+10	1.45E+12
FDI inflow	93	1.19E+10	1.75E+10	5640000	7.91E+10
Renewable usage (% of total energy usage)	91	25.34353	14.0386	0.962	53.8

Chapter 4

Results

The following table provides estimation results on the relationship between CO2 emissions and economic growth in the USA from 1981-2006:

Table 3 (USA): Dependent Variable = log (CO2 emissions per capita)

Independent Variable	Coefficient
GDP per capita	.0000448**
	(.00002)
GDP per capita squared	-6.99e-10*
	(3.39e-10)
Industry share in GDP	.0001512
	(.0054587)
Log (energy consumption)	-1.057504*
	(.60465)
Log (fossil fuel energy consumption)	1.93369***
	(.572)
Year	-0.0058961
	(.0049889)
Constant	-19.43753**
	(8.302118)
Obs	24
F(6, 17)	65.28
Prob > F	0.000
R-squared	0.958

(standard error)

*** = significant at 99% level

**= significant at 95% level

*= significant at 90% level

The estimation results provided above do support the existence of an Environmental Kuznets Curve when describing the relationship between CO2 emissions per capita and GDP per capita in the United States from 1981-2006. As expected, the coefficient on GDP per capita squared is negative which allows for a cutoff point which corresponds to $32,045 per person. The F-stat and R squared values indicate this model is valid and explains most of the variation in the dependant variable, however the coefficients for industry share of GDP, energy consumption and time are statistically insignificant. It must be noted here that the United State's turning point for environmental improvement roughly corresponds to the point where CO2 emissions per capita reaches 19.5 metric tons per person.

The following table provides estimation results on the relationship between CO2 emissions and economic growth in the BRIC countries from 1981-2006:

Table 4 (BRIC): Dependent Variable = log (CO2 emissions per capita)

Independent Variable	Coefficient
GDP per capita	.0012764***
	(.0001033)
GDP per capita squared	-2.32e-07***
	(2.23e-08)
Industry share in GDP	-.0259607***
	(.0035589)
Log (energy consumption)	-3.29901***
	(.2883297)
Log (fossil fuel energy consumption)	3.553854***
	(.2106121)

Year	-.0415898***
	(.0044824)
Constant	-20.51145***
	(1.815795)
Obs	85
Wald chi2 (6)	4061.58
Prob > chi2	0.0000
R-squared overall	0.98

(standard error)

*** = significant at 99% level

**= significant at 95% level

*= significant at 90% level

Once again the above estimation results provide support for a relationship between CO2 and GDP per capita in the BRIC countries which follows an Environmental Kuznets Curve. The coefficient on GDP per capita squared is negative which allows for the inverted u-shaped curve. All the coefficients are statistically significant in difference from zero. It must be noted here that the cutoff point for the BRIC countries corresponds to a value of $2,751 per person, with improvement occurring after CO2 emission per capita reaches 10 metric tons per person.

It is not necessarily surprising that the cutoff point is much lower for the BRIC countries (all figures for GDP per capita are converted into 2000 $US) since GDP per capita levels are much higher for the United States throughout this period. However what is more surprising is the fact that the cutoff point corresponds with a lower CO2 per capita emission level for the BRIC countries when compared with the United States. As

mentioned above, the pollution haven hypothesis indicates that a developed country such as the United States will look to shift production to developing countries such as the BRIC as a way of taking advantage of less environmental regulation. Additionally this theory would predict that the BRIC would look to decrease regulation as a way of promoting investment. However the results above indicate that the United States is more willing to accept pollution as a way of increasing per capita income. Whereas as the income effect occurs for the BRIC countries at an earlier stage since they are willing to buy back pollution at a lower point of emission levels.

The main explanation for the results found above is that the above model is only the standard benchmark model for the EKC. In order to understand the differences in the cutoff points from the examples, we must also include variables which incorporate differences in the characteristics between the two sets of countries. For example the United States is a developed country which is why the share of production from agriculture, industry, or services will be different when compared with the BRIC countries. Additionally since we are considering CO2 emissions levels, then the type, source and pattern of energy use could affect emission levels between developed and developing countries. The distribution of energy from fossil fuels vs. renewable sources could impact emission levels, and a developed country such as the United States may have better technology or more access to clean energy sources. Furthermore, the BRIC countries are characterized by rapid growth and increased investment levels which influence CO2 emission levels. All of these issues will be examined in the next section as a way of explaining the difference in the turning point for CO2 emission levels.

Chapter 5

USA vs. BRIC

Initially let's look at how investment levels affect CO2 emission levels. Previous literature has given mixed results about the effect of FDI inflows on environmental degradation. Some studies have shown that an increase in inflows leads to an increase in overall production levels which are associated with more pollution. Alternatively some studies have shown that FDI inflows are already an indicator of low GDP per capita. Therefore FDI inflow has the effect of increasing R&D in technologies which are more energy efficient which reduces emission levels.[11]

Additionally the share of production from the different types of sectors could have an impact on CO2 emission levels. For example the BRIC countries are rapidly developing therefore industry value added as a percentage of GDP should be greater when compared to the United States. Alternatively the United States as a developed country should have a larger contribution from the service sector as a percentage of GDP. A quick look at the data indicates that the average value of industry value added as percentage of GDP is 26.9% for the United States and 36.6% for the BRIC during this time period. Average value of services value added as percentage of GDP is 71.2% for the United States and 46.6% for the BRIC. The industry sector is more pollution intensive than the services sector and this difference needs to be accounted for.

Furthermore, renewable energy sources is becoming a trendy subject because of its potential impact on global energy consumption patterns and pollution emission levels.

[11] Tamazian, Chousa, and Vadlamannati 2009 pg. 250-52

A renewable energy source is energy generated from natural resources such as solar, wind, heat, tides or biomass. Most of these energy sources are more environmental friendly when compared with fossil fuel sources. Data on pattern of energy usage varies when comparing the United States and the BRIC. The United States and China consume the most amount of energy from fossil fuel sources (as percentage of total energy usage). It would be interesting to see how the results from above change when controlling for type of energy usage. The tables provided below estimate the standard Environmental Kuznets Curve while controlling for three additional factors. First of all services value added as percentage of GDP is added to the model to control for differences in share of production, FDI inflows is added to determine the effect of level of investment, and the percentage of total energy usage coming from renewable sources is added to control for pattern of energy usage.

The following table provides estimation results on the relationship between CO2 emissions and economic growth in the USA from 1981-2006 and includes all the new control variables mentioned above:

Table 5 (USA): Dependent Variable = log (CO2 emissions per capita)

Independent Variable	Coefficient
GDP per capita	.0000443**
	(.0000206)
GDP per capita squared	-7.06e-10*
	(3.4e-10)
Service share in GDP	.0012408
	(.0051406)
Log (energy consumption)	-1.01164

	(.635633)
Log (fossil fuel energy consumption)	1.773532**
	(.6209265)
Year	-.00587
	(.0054951)
Log (FDI inflow)	.0061894
	(.0074783)
Renewables (% of total energy use)	-.0169392
	(.0147206)
Constant	-15.69753
	(9.257874)
Obs	24
F (8, 15)	49.14
Prob > F	0.0000
R-squared	0.9632

(standard error)

*** = significant at 99% level

**= significant at 95% level

*= significant at 90% level

The above estimation results provide mixed evidence about the existence of an Environmental Kuznets Curve. Specifically the coefficients on GDP per capita and GDP per capita squared are statistically significant in difference from zero and have their expected signs. However the coefficients on services value added, FDI inflow, and index for renewable energy usage are statistically insignificant. This doesn't help in explaining why the threshold points are different for the United States compared with the BRIC countries. Additionally this model doesn't provide evidence of a significantly different

cutoff point for environmental improvement in the United States than the one discovered earlier.

The following table provides estimation results on the relationship between CO2 emissions and economic growth in the BRIC countries from 1981-2006 and includes all the new control variables mentioned above:

Table 6 (BRIC): Dependent Variable = log (CO2 emissions per capita)

Independent Variable	Coefficient
GDP per capita	.0005157***
	(.0000744)
GDP per capita squared	-1.12e-07***
	(1.46e-08)
Service share in GDP	.006623**
	(.0027629)
Log (energy consumption)	.4844607
	(.5813453)
Log (fossil fuel energy consumption)	-.2482965
	(.580286)
Year	-.0190001***
	(.0040011)
Log (FDI inflow)	-.0522559***
	(.0107587)
Renewables (% of total energy use)	-.0561846***
	(.0087427)
Constant	-2.357749
	(3.264397)
Obs	85
Wald chi2 (8)	9438.00

Prob > chi2	0.0000
R-squared overall	0.992

(standard error)

*** = significant at 99% level

**= significant at 95% level

*= significant at 90% level

The above estimation results provide strong evidence for the existence of an Environmental Kuznets Curve. The coefficients for GDP per capita and GDP per capita squared are statistically significant in difference from zero and have their expected signs. Coefficients for FDI inflow and renewable energy usage are statistically significant and negative. This provides evidence that as the BRIC countries shift to alternative energy sources their emission levels should go down. Additionally the sign on FDI inflow supports the previously stated hypothesis that investment will promote R&D into technologies which are more efficient and cause less pollution. Also this model doesn't provide evidence of a cutoff point for the BRIC countries that is significantly different than the one reported earlier.

Chapter 6

Conclusion

This research provides evidence in favor of the existence of an Environmental Kuznets Curve when explaining the relationship between CO2 emissions and economic growth in the United States and the BRIC countries. Specifically the threshold or cutoff point for the United States is $32,045 and for the BRIC countries it is $2,751. This is not necessarily surprising since the United States is the world's largest economy and has been able to maintain fairly stable GDP growth rates. The United States has the world's largest GDP and has considerably higher GDP per capita values when compared with the still developing BRIC countries. However what isn't necessarily clear is why the threshold for environmental improvement is higher for the United States (19.5 metric tons per capita) than for the BRIC countries (10 metric tons per capita).

This provides mixed support for the pollution haven hypothesis which in this case correctly predicts that investment into developing countries (the BRIC) is increasing. However the BRIC countries seem to be more willing to buy back pollution. This can be explained by characteristic differences in the two examples. First of all the United States has already gone through the process of development and incorporated technologies which allow for a reduction in emission standards. The BRIC countries have the advantage of using their trading partner's example by for example buying cheaper more efficient production technologies already developed by the United States. This is supported by the estimation results which suggest a negative coefficient on FDI inflows for the BRIC. Alternatively it could be argued that FDI has a spillover effect which

allows for advanced technology from a developed country to be transferred to a developing country which would help in reducing emission levels.

Additionally data seems to suggest that the BRIC countries are becoming more inclined towards renewable energy sources and the benefits gained from them. Renewable energy is becoming synonymous with reduction in CO2 emissions and an increase in energy from this source (as a percentage of GDP) has the effect of decreasing emission levels when compared with countries that are more reliant on fossil fuel sources. Evidence of this comes from the fact the coefficient on renewable energy is negative for the BRIC countries.

The last issue that could be used to explain this disparity is incentives. The United States is the world's largest economy and has been criticized for being the largest polluter. One wouldn't necessarily consider reducing CO2 emissions unless there is an incentive to do so. For example it has been suggested that certain economies (mostly in the north) could gain from a rise in emissions which would lead to rise in temperatures. This could lead to a boost in the local economy through for example agriculture production which previously wasn't possible. On the other hand societies which live close to sea level have an incentive to reduce CO2 emissions because it causes a rise on water levels which directly affects them. Therefore the BRIC may have more of an incentive to reduce CO2 emission levels than the United States. Estimating the impact of incentives within each country was not possible for this study and is a suggestion for further research.

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